

BACKGROUND OF THE INVENTION

5

2. Terminology

10

15

3. Description of Related Art

20

30

[illegible]

5

10

25

30

Q. Now, you said that you were not sure if the person was a man or a woman, but you were sure that it was a person of color, is that correct?

and the undesired torque change during transient period from one to the other of the two intake air controls is suppressed.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a system
5 and method for controlling intake air to an internal combustion
engine such that the occurrence of violent torque variation
caused by aggressive cyclic depression and release manipulation
of an accelerator pedal is prevented and the undesired torque
change during transient period from one to the other of the two
10 intake air controls is suppressed.

According to one aspect of the present invention there is provided a method for controlling intake air of an internal combustion engine, the engine having at least one combustion chamber provided with intake means together with an intake manifold provided with a throttle valve, wherein the opening and closure timings of the intake means are adjustable entirely independently from the crankshaft position to control the amount of intake air supplied to the combustion chamber, the method comprising:

20 *providing a response adjustment to variable valve timing*
 control of the intake means for unthrottled intake air control.

According to another aspect of the present invention, there is provided a system for controlling intake air of an internal combustion engine, the engine having at least one combustion chamber provided with intake means together with an intake manifold provided with a throttle valve, wherein the opening and closure timings of the intake means are adjustable entirely independently from the crankshaft position to control the amount of intake air supplied to the combustion chamber, the method comprising:

a control for a response adjustment to variable valve timing control of the intake means for unthrottled intake air control.

[illegible]

Figure 1 is a block diagram illustrating a system and method for controlling intake air to an internal combustion engine according to the present invention.

Figure 3 is a block diagram of a control unit implementing the present invention.

Figure 5 is a graph illustrating intake air control schedule.

Figure 6 is a graphical representation of retrievable mapped data of various values of target airflow rate against varying values of accelerator angular position (VAPO) with varying values of engine speed (NE) as parameter.

Figure 7 is a graphical representation of retrievable mapped date of values of intake valve closure (IVC) timing of intake means against varying values of target airflow rate.

Figure 8 is a mathematical representation of a response adjuster used in Figure 4.

Figure 9 is a schematic representation of retrievable mapped data of response correction coefficient represented by the reference character FLOAD.

Figure 10 is a flow chart illustrating control logic according to the present invention.

Figures 11A, 11B and 11C are graphical representations illustrating engine response performance with the benefit of the present invention as compared to engine response performance without the benefit of the present invention.

Figure 1 is a block diagram illustrating operation of a system or method for controlling intake air by variable intake

Engine 12 includes various other sensors such as a
30 crankshaft sensor or engine speed sensor 54, which provides a
signal indicative of engine speed (NE) to C/U 14, and an engine
coolant temperature sensor 56. Engine coolant temperature
sensor 56 provides an engine coolant temperature (Tw) signal

2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2729 2730 2731 2732 2733 2734 2735 2736 2737 2738 2739 2740 2741 2742 2743 2744 2745 2746 2747 2748 2749 2750 2751 2752 2753 2754 2755 2756 2757 2758 2759 2760 2761 2762 2763 2764 2765 2766 2767 2768 2769 2770 2771 2772 2773 2774 2775 2776 2777 2778 2779 2780 2781 2782 2783 2784 2785 2786 2787 2788 2789 2790 2791 2792 2793 2794 2795 2796 2797 2798 2799 2800 2801 2802 2803 2804 2805 2806 2807 2808 2809 2810 2811 2812 2813 2814 2815 2816 2817 2818 2819 2820 2821 2822 2823 2824 2825 2826 2827 2828 2829 2830 2831 2832 2833 2834 2835 2836 2837 2838 2839 2840 2841

indicative of the engine coolant temperature to C/U 14.

Figure 2 provides a schematic view of an EMD 86, which is used in each of valve controls 34 and 38, for the associated cylinder valve, for example, intake valve 32. EMD 86 includes a housing 88, a movable plate 90 is kept in a neutral position, as illustrated in Figure 2, within housing 88 by means of two springs 92 and 94. Springs 92 and 94 are arranged on one and the opposite sides of movable plate 90. At the remotest ends, springs 92 and 94 bear against housing 88. At the nearest ends, springs 92 and 94 bear against spaced walls of movable plate 90. Two electromagnetic coils 96 and 98 are mounted to housing 88 on one and the opposite sides of movable plate 90. With no supply of electric current through electromagnetic coil 98, supply of electric current through electromagnetic coil 96 attracts movable plate 90 for movement against the action of spring 92. Supply of electric current through electromagnetic coil 98 with no supply of electric current through electromagnetic coil 96 attracts movable plate 90 for movement against the action of spring 94. In order to transmit at least movement of movable plate 90 in a direction against spring 94 to intake valve 32, the valve stem is operatively connected to movable plate 90. Thus, with no supply of electric current through electromagnetic coil 96, supply of electromagnetic coil 98 can hold intake valve 32 lifted from a rest position where intake valve 32 rests on a valve seat 102. In this embodiment, valve stem 100 is fixed to movable plate 90 so that supply of electric current through electromagnetic coil 96 with interruption of supply of electric current through electromagnetic coil 98 can hold intake valve 32 to the rest position.

Referring to Figure 3, C/U 14 receives signals from the various sensors via input ports 104, which may provide signal conditioning, conversion, and/or fault detection as well known in

the art. Input ports 104 communicate with processor (MPU) 106 via a data/control bus 108. MPU 106 implements control logic in the form of hardware and/or software instructions, which may be stored in a computer-readable media 110 to effect intake air control for engine 12. Computer-readable media 110 may include various types of volatile and nonvolatile memory such as random-access memory (RAM) 112, read-only memory (ROM) 114, and keep-alive memory (KAM) 116. These functional classifications of memory may be implemented by one or more different physical devices such as PROMs, EPROMs, EEPROMs, flash memory, and the like, depending upon the particular application.

Sub MPU 106 communicates with various actuators of engine 12 via output ports 118. Actuators may control ignition timing or spark SPK, timing and metering of fuel FIV, position of throttle valve TVA to control air inflow, intake valve timing (IVT) to control intake air into combustion chamber and exhaust valve timing (EVT). In operation range where throttled intake air control is required, the position of throttle valve 44 is variably adjusted by an actuator in the form of a motor 45 to control intake air into combustion chamber 16 and intake valve closure (IVC) timing is adjusted by EMD 86 to provide a valve opening duration in the neighborhood of the least duration. In operation range where unthrottled intake air control is required, IVC control is performed and the position of throttle valve 44 to adjusted so as to maintain boost pressure within intake manifold at a target negative pressure value. In IVC control, intake valve closure (IVC) timing is variably adjusted to control intake air into combustion chamber 16 without relying on throttling of airflow by throttle valve 44.

Figure 5 illustrates, by a shadowed area, low-load high-speed operation range where throttled intake air control is to be performed. An area not shadowed in Figure 5 illustrates

operation range where throttled intake air control is to be performed.

In the low-load high-speed operation range, it is impossible to accomplish a target intake air by early valve closure timing because the minimum valve opening duration is determined independently of the crankshaft position and speed by EMD 86.

With the minimum valve opening duration having the earliest valve closure timing, increasing the crankshaft speed results in a delay in valve closure timing in terms of crankshaft angular position. Thus, in the low-load high-speed operation range as indicated by the shadowed area in Figure 5, it is impossible to accomplish the target intake air by early intake valve closure with the wide open throttle (WOT).

In a preferred embodiment, in operation range not shadowed in Figure 5, unthrottled intake air control is performed to accomplish a target value by variably adjusting IVC timing with boost pressure within intake manifold 26 maintained constant by variably adjusting throttle valve 44. In low-load high-speed operation range as indicated by shadowed area in Figure 5, throttled intake air control is performed to accomplish a target value by variably adjusting throttle position of throttle valve 44 to vary the boost pressure with the IVC timing adjusted in the neighborhood of the minimum valve opening duration.

Sub 3 In the preferred embodiment, MPU 106 executes instructions stored in computer-readable media 110 to carry out a method for intake air control to communicate with EMD 34 of for intake valve 32 and motor 45 for throttle valve 44 for unthrottled intake air control in coordination with throttled intake air control.

Figure 4 provides a block diagram illustrating representative controllers for intake air control to provide engine torque control.

Block 120 provides its output TQH0SH to a block 124. Block 124 inputs NE as well as TQH0SH and performs control mode selection. Block 124 compares the input value of TQH0SH with a threshold value on a curve 126 defining the boundary of the part-load high-speed operation range illustrated by the shadowed area in Figure 5. For obtaining the threshold value on curve 126, a table look-up operation of mapped data of values in intake air on curve 126 against the input value of NE. The

5

10

15

20

25

30

operations against the current input value of IVC and the preceding or old value of the processed or final target intake valve closure timing FIVCOLD to provide two retrieved values. Using these two retrieved values, an interpolation is made to an appropriate value of FLOAD against the current value of NE. In the illustration, only one set of FLOAD maps are used to provide FLOAD. Preferably, different sets of FLOAD maps should be provided and used for acceleration and deceleration, respectively.

As illustrated in Figure 18, using as inputs IVC and FLOAD, block 128 generates, as an output, FIVC by calculating the following equation:

$$FIVC = IVC \times FLOAD + FIVCOLD \times (1 - FLOAD) \dots (1).$$

where: FIVCOLD is an old or preceding value of FIVC.

Block 128 provides FIVC to a control loop for EMD 34. The control loop determines a control signal in response to FIVC and provides the control signal to EMD 34 for closing intake valve 32 at the closure timing as indicated by determined IVC timing.

In the preferred embodiment, the valve opening and valve closure timings of intake valve 32 for throttled intake air control are such that the valve opening timing is held at a crankshaft position near the top dead center (TDC) and the valve closure timing is variably shifted to a crankshaft position falling within a range between the crankshaft position of the valve opening timing and the bottom dead center (BDC).

Let us now assume that throttled intake air control mode is selected in block 124. In this case, block 124 provides TQH0SH to block 138 for determination of TVA for throttled intake air control mode. Concurrently with the selection of throttled intake air control mode, a block 140 for determination of IVC for throttled intake air control mode is triggered to put into

operation in response to a signal as indicated by an arrow 139.

For determination of TVA for throttled intake air control in block 138, MPU 106 determines area A_{TH} against TQHOSH and NE. Then, MPU 106 conducts conversion of the determined area A_{TH} to a target throttle position TVA by performing a look-up operation of a table against A_{TH} . Block 138 provides TVA to motor 45 for throttle valve 44.

For determination of IVC for throttled intake air control in block 140, MPU 106 inputs NE and determines as a function of NE a target value of IVC timing to accomplish the minimum valve opening duration at the input value of NE. Block 140 determines a control signal in response to the determined IVC timing and provides control signal to EMD 34 for closing intake valve 32 at the closure timing as indicated by determined IVC timing.

15 An example of how C/U 14 would implement the present invention can be understood with reference to Figure 10. The flow chart of Figure 10 illustrates control logic for providing intake valve closure timing for unthrottled intake air control according to the present invention. One of ordinary skilled in the art will recognize that the control logic may be implemented in software, hardware, or a combination of software and hardware. Likewise, various processing strategies may be utilized without departing from the spirit or scope of the present invention. The sequences of operations illustrated is not necessarily required to accomplish the advantages of the present invention, and provided for ease of illustration only. Likewise, various steps may be performed in parallel or by dedicated electric or electric circuits.

In Figure 10, step 150 represents input of VAPO. Step 152
30 represents input of NE. Step 154 represents determination of
TQH0SH. Step S156 represents input of NE. Step 158
represents determination of IVC for throttled intake air control.
Step 160 represents response adjustment in the manner as

2025 RELEASE UNDER E.O. 14176

described in connection with Figures 8 and 12 to give FIVC. Step 162 represents output of FIVC.

5 *Subst* Referring to Figures 11A, 11B and 11C, the fully drawn line in each of Figures 11B and 11C illustrates a smooth transient response characteristic with the benefit of the present invention in response to a step-like increase of VAPO as illustrated in Figure 14A. The dotted line in each of Figures 11B and 11C illustrates a transient response characteristic without the benefit of the present invention.

10 In the preceding description, the response adjustment is made on the output IVC of block 134. If desired, a response adjustment may be made on the input TQH0SH of block 134. In this case, a block 128A for response adjustment is provided and give a final or processed value FQH0ST by performing
15 mathematical calculation that may be expressed as:

$$FQH0ST = (TQH0SH \times FLOAD + FQHOLD \times (1 - FLOAD)) \dots (2).$$

Block 128A provide FQH0ST to block 134. In this case, block
20 134 determines IVC based on the input value of FQH0ST.

While the present invention has been particularly described, in conjunction with preferred embodiment, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the foregoing
25 description. It is therefore contemplated that the appended claims will embrace any such alternatives, modifications and variations as falling within the true scope and spirit of the present invention.

This application claims the priority of Japanese Patent
30 Application No. 11-345374, filed December 3, 1999, the disclosure of which is hereby incorporated by reference in its entirety.

0010274552260